Response of Arabidopsis thaliana to elevated CO2 en SO2

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Summary

Industrial activities and excessive burning of fossil fuel around the world has resulted in a substantial increase of the atmospheric CO_2 and SO_2 concentration. In this thesis the response of *Arabidopsis thaliana* and *Senecio vulgaris* to elevated atmospheric concentrations of CO_2 and SO_2 was investigated. The central issue investigated in this study was the effect of both gaseous air-pollutants on plant metabolism and fitness, with regard to the plants life strategy as a fast growing annual with a short life cycle.

In Chapter 2 *Arabidopsis thaliana* was exposed to an elevated CO_2 concentration of 700 $\mu l\ l^{-1}$ CO_2 beginning directly after germination until the end of the life cycle. An increase in dry mass production of 56% was observed in comparison to plants growing at ambient CO_2 concentration of 350 $\mu l\ l^{-1}$. The stimulation of the structural biomass production must be ascribed to a short transient stimulation of the relative growth rate (RGR), lasting for one to maximally two days. Thereafter, a similar RGR was observed at both CO_2 concentrations. The rate of photosynthesis was stimulated at elevated CO_2 and no acclimation of photosynthesis was observed after prolonged exposure. Dry matter content was increased at elevated CO_2 which could solely be attributed to the increase of the leaf starch content. Nitrogen content was lower in plants growing at elevated CO_2 but this was solely due to the increase in leaf starch content and the nitrogen content expressed on a fresh weight basis was hardly affected. The combined stimulation of structural biomass and starch content resulted in a substantial increase of the plant fitness reflected in a 51% increase in seed production.

In Chapter 3 *A. thaliana* was exposed to various concentrations of CO_2, ranging from 390 to 1680 $\mu l\ l^{-1}$. Maximal stimulation of the shoot structural biomass production was already reached at a CO_2 concentration of 560 $\mu l\ l^{-1}$. However, the accumulation of starch continued until the highest applied concentration of 1680 $\mu l\ l^{-1}$. The content of soluble sugars and soluble phenolics were not affected by elevated CO_2, except for the highest applied concentration. Photosynthetic capacity was not affected by elevated CO_2 exposure and also the chlorophyll content was hardly affected. The storage capacity of assimilatory starch in the shoot of *A. thaliana* is high and this may be involved in the absence of any disturbance of carbohydrate metabolism and photosynthesis at elevated CO_2.

Thirteen different lines of *A. thaliana* from a world-wide origin were tested for their response to exposure to an elevated CO_2 concentration of 700 $\mu l\ l^{-1}$ in Chapter 4. All *A. thaliana* lines show an increase in biomass production, an increase in starch content and a hardly affected soluble sugar content. The latter seems to be a species characteristic. Intra-specific variation existed in the absolute amount of biomass stimulation at elevated CO_2. Part of these differences might be explained by a combination of different factors since lines with thicker leaves

seem to profit less from elevated CO_2 and slower growing lines tend to profit more from the elevated CO_2 than faster growing lines did.

In Chapter 5 the SO_2 response of *A. thaliana* to exposure to SO_2 , which is a potent phytotoxic gas, was investigated. *A. thaliana* appeared to be rather SO_2 tolerant. Over a large range of SO_2 concentration up to 0.7 $\mu l\ l^{-1}$ no negative effects on plant growth were observed. A linear relation was observed between the rate of deposition and the atmospheric SO_2 concentration, which resulted in a substantial accumulation of sulfur in the shoot. The main part, 75%, of this absorbed atmospheric sulfur was accumulated as sulfate. The other part could be revealed in the organic sulfur fraction. This 3:1 distribution in sulfate to organic sulfur was irrespective of the applied concentration. The sulfur to nitrogen ratio of the organic fraction was hardly affected indicating no drastic changes in composition or specific accumulation of sulfur rich compounds. Although the shoot content of water-soluble non-protein thiols and glucosinolates was higher upon exposure to SO_2 their contribution to the detoxification of SO_2 was only small. The linear relation between the uptake of SO_2 and the applied concentration was irrespective of the air temperature and only depending on the stomatal conductance as presented in Chapter 6. In contrast the uptake of H_2S showed saturation kinetics.

In Chapter 7 the potential rate of sulfur metabolism was varied by varying the nitrogen availability of *S. vulgaris*, which is a species more susceptible for SO_2 than *A. thaliana*. The uptake rate of SO_2 by *S. vulgaris* were comparable to *A. thaliana* but *S. vulgaris* accumulated to a large extent thiols. Plant biomass production was negatively affected at concentrations above 0.2 $\mu l\ l^{-1}$ SO_2. A substantial increase of sulfate content was observed almost linear to the applied SO_2 concentration and irrespective of the nitrogen nutrition level. The relative decrease in plant biomass production as a result of the SO_2 exposure was irrespective of the applied nitrogen nutrition level. Apparently, the potential to incorporate excessive atmospheric deposited sulfur into organic sulfur at the higher nitrogen nutrition levels did not affect the phytotoxic response towards SO_2 exposure of *S. vulgaris*.

In Chapter 8 thirteen different lines of *A. thaliana* with a world-wide origin were tested in their response to 0.7 $\mu l\ l^{-1}$ SO_2 in order to get more insight into the variability in response to SO_2 within the species. In general the responses of the different lines were similar except for one line, N922, originating from Tadjikistan, which showed an acute phytotoxic response negatively affecting growth and inducing leaf necrosis. All lines accumulated sulfate to a large extent and had a relatively small disturbance of the thiol content. SO_2 tolerance seems to be a species characteristic for *A. thaliana*.

As a ruderal plant species, normally exposed to limiting vegetative expansion and continuous resource capture, *A. thaliana* exhibits an enormous capacity to accumulate available resources during its short vegetative life span. This might ing lines tend to profit

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explain the high vacuolar and plastid accumulation of sulfate and starch, respectively, without any negative effects on plant growth and functioning. In addition, *A. thaliana* seems to be a stress tolerator as might be concluded from its high SO_2 tolerance. Therefore, its life strategy might explain its indifferent or even positive response to an anthropogenic induced change of the atmospheric composition.